A detailed illustration of the TerraLuna satellite in space. The satellite is a complex, multi-faceted structure with gold-colored thermal insulation, blue solar panels, and a large white parabolic dish antenna. It is positioned in the foreground, with the curved horizon of the Earth visible below it. In the background, the Earth is shown as a blue and white sphere, and the dark, cratered surface of the Moon is visible in the upper right corner.

explore the connection between earth and moon
map the surface of the moon

appropriate for grades 7-9
keywords: moon, solar system, geology, volcanism, craters
citizen science

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CosmoQuest & the SIUE STEM Center
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TerraLuna

TerraLuna

explore the connection between earth and moon
map the surface of the moon

This unit was produced by
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and builds on the *MoonMappers* citizen science project.

This is a joint production of
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Instructor's Guide

About Citizen Science

Citizen science is an engaging way for you and your students to have meaningful experiences in Science, Technology, Engineering, and Mathematics (STEM). Although there are many different types of citizen science projects happening all over the world, most of them can be thought of as

a collaboration of professional scientists and non-professional volunteers (citizen scientists) engaged in authentic scientific research.

Citizen scientists are ordinary people of all ages and interests, from weather observers and bird watchers to amateur astronomers and computer programmers! They experience the processes of science first hand as they help scientists to collect, analyze, and sometimes even interpret large amounts of data. They communicate their experiences and their findings to each other and to the public through blogs, forums, social media, and face-to-face meetings and conferences. Citizen science brings many, many opportunities to learn new things and to meet new friends.

Encourage your students to become citizen scientists! They will practice 21st Century Skills--critical thinking, communication, and collaboration--as well as science processes, all while learning amazing new things about the world around them. Exploring the Moon with CosmoQuest's *TerraLuna* and Moon Mappers is a great way to get started. Enjoy!

Instructor's Guide

Introduction

This unit introduces teachers and students to the *Moon Mappers* citizen scientist project, which is part of the *CosmoQuest* online community at <http://cosmoquest.org/>. *CosmoQuest* seeks to create and support a vibrant, global community of teachers and learners who explore and share their universe through citizen science. The popular and successful citizen science projects it contains, (*Planet Mappers*, *Asteroid Mappers*, and more), use the efforts of volunteers to help researchers analyze the flood of data that confronts them. Through citizen science projects, many unique scientific discoveries have been made, ranging from individual discoveries to those using classifications that depend on the input of everyone who has visited the site.

The theme of this unit is the exploration of the geology of the Moon as it compares to the geology of Earth. In days one and two, students discuss reasons for Moon exploration and investigate the origin of the Moon. During days three through seven, students are challenged to learn all they can about the different geological processes on the Moon. In days eight through thirteen, they make a real contribution to science by mapping craters as they continue discussing lunar exploration. Through this inquiry process, students not only learn science content, but also science and engineering practices.

The content of the unit was intended for middle school students (grades 7-9), but is easily adapted for high school students.

The lessons in this unit follow the Biological Sciences Curriculum Study (BSCS) 5E instructional model. For more information on this inquiry lesson format, see <http://www.bscs.org/bscs-5e-instructional-model>.

Beginning the Unit

Content and Resources

See the first section of the Exploring the Moon Educator Guide

(http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/The_Moon_Gateway_Teachers_Guide.html) by NASA titled “The Moon – Gateway to the Solar System Teachers’ Guide.” We will also include helpful resources on the CosmoQuest Educators’ Zone at <http://cosmoquest.org/x/educatorszone/terraluna-connecting-earth-and-moon/>.

Technology Expectations

The overarching goal of the unit is to engage students in authentic scientific research that is conducted through citizen science projects. Because *Moon Mappers* is web-based, computer access is an implied necessity for this unit. The minimum number of computers is one per student team, bearing in mind that more than three students at a computer may result in student disengagement in the activity. In addition, a white board, Promethean[®] Board, SMART[®] Board, or other classroom projection system will facilitate the presentation of the instructional material.

Mapping the Moon

The *Moon Mappers* project can be found at http://cosmoquest.org/projects/moon_mappers/. On Day Nine of the unit, you will be guiding your students through the process of marking craters by using the tutorial at the *Moon Mappers* website. It is strongly recommended that you become familiar with the tutorial and the process of marking craters before you present the information to your students. See http://cosmoquest.org/Moon_Mappers:_Simply_Craters_Tutorial

Student Teams

Before you begin teaching the unit, arrange your class in teams of three to five students. Many of the activities in the unit, like the process of science itself, require collaboration. As you assign the teams, be sure to mix skill and ability levels. Also keep in mind the number of available computers and arrange the teams to allow members easy access to them.

Student Journals

A good way to help students integrate their learning during the unit is to ask them to keep a Moon Exploration Journal. The journal can include notes on vocabulary words and concepts, class assignments, and their own personal observations. The journals can also be used as a tool for assessment and a link to language arts skills.

Teaching the Unit

For each lesson, the “Engage” through “Evaluate” sections are planned to fill one 50-minute class period. You may find it necessary to adjust segments of the lesson to fit the needs of your class, your own teaching style, and the amount of time available. However, it is necessary to present the first four “Es” in the order listed to preserve the process of inquiry that the lesson intends.

Many of the lessons offer more than one activity to explore the content. These options are separated by the word “OR” in the plans. You may choose to use more than one option to reteach difficult concepts or to extend the unit.

The ideas in the “Elaborate” and “Cross-Curricular Links” sections are meant to enrich the lesson and integrate learning in other subject areas. These activities are optional and could be provided as opportunities for homework or extra credit. If they are used as class activities, each would require one additional 50-minute class period.

Ending the Unit

The posttest provided may be too extensive for the purposes of your classroom. Feel free to use the test as a question bank and choose just those items appropriate for your students.

Standards

The authors have chosen to use the Next Generation Science Standards, posted at <http://www.nextgenscience.org/>, as the basis for the lessons in this unit. See the unit overview for a list of standards addressed by each lesson.

Efforts were made in Cross-Curricular Links to include standards from the Common Core (<http://www.corestandards.org/>) for math, language arts, and social studies. Pertinent standards from AAAS's *Project 2061 Benchmarks for Science Literacy* (<http://www.aaas.org/program/project2061>) and National Science Education Standards (http://www.nap.edu/openbook.php?record_id=4962) are listed below for the unit.

The National Science Education Standards (NSES)

(http://www.nap.edu/openbook.php?record_id=4962)

- **Content Standard A (Science as Inquiry)**

As a result of activities in grades 5-8, all students should develop:

1. Abilities necessary to do scientific research.
 - a. Identify questions that can be answered through scientific investigations.
 - b. Use appropriate tools and techniques to gather, analyze, and interpret data.
 - c. Develop descriptions, explanations, predictions, and models using evidence.
 - d. Think critically and logically to make the relationships between evidence and relationships.
 - e. Communicate scientific procedures and explanations.
2. Understanding about scientific inquiry.
 - a. Mathematics is important in all aspects of scientific inquiry.
 - b. Scientific explanations emphasize evidence, have logically consistent arguments, and use scientific principles, models, and theories. The scientific community uses such explanations until displaced by better scientific ones.
 - c. Science advances through legitimate skepticism.
 - d. Scientific investigations sometimes result in new ideas and phenomena for study, generate new methods or procedures for an investigation, or develop new technologies to improve the collection of data.

As a result of activities in grades 9-12, all students should develop:

1. Abilities necessary to do scientific research.
 - a. Identify questions and concepts that guide scientific investigations.
 - b. Design and conduct scientific investigations.
 - c. Use technology and mathematics to improve investigations and communications.
 - d. Formulate and revise scientific explanations and models using logic and evidence.
 - e. Recognize and analyze alternative explanations and models.
 - f. Communicate and defend a scientific argument.

2. Understanding about scientific inquiry.
 - a. Conceptual principles and knowledge guide scientific inquiries. Historical and current scientific knowledge influence the design and interpretation of investigations and the evaluation of proposed investigations made by other scientists.
 - b. Scientists conduct investigations for a wide variety of reasons.
 - c. Scientists rely on technology to enhance the gathering and manipulation of data.
 - d. Mathematics is essential in scientific inquiry.
 - e. Scientific explanations must adhere to criteria such as: a proposed explanation must be logically consistent; it must abide by the rules of evidence; it must be open to questions and possible modification; and it must be based on historical and current scientific knowledge.
 - f. Results of scientific inquiry—new knowledge and methods—emerge from different types of investigations and public communication among scientists.
- **Content Standard D (Earth and Space Science)**
As a result of their activities in grades 5-8, all students should develop an understanding of:
 1. Structure of the Earth System
 - a. The solid earth is layered with a lithosphere; hot, convecting mantle; and dense, metallic core. Lithospheric plates on the scales of continents and oceans constantly move at rates of centimeters per year in response to movements in the mantle. Major geological events, such as earthquakes, volcanic eruptions, and mountain building, result from these plate motions.
 - b. Land forms are the result of a combination of constructive and destructive forces. Constructive forces include crustal deformation, volcanic eruption, and deposition of sediment, while destructive forces include weathering and erosion.
 - c. Some changes in the solid earth can be described as the "rock cycle." Old rocks at the earth's surface weather, forming sediments that are buried, then compacted, heated, and often recrystallized into new rock. Eventually, those new rocks may be brought to the surface by the forces that drive plate motions, and the rock cycle continues.
 - d. Soil consists of weathered rocks and decomposed organic material from dead plants, animals, and bacteria. Soils are often found in layers, with each having a different chemical composition and texture.
 2. Earth's History
 - a. The earth processes we see today, including erosion, movement of lithospheric plates, and changes in atmospheric composition, are similar to those that occurred in the past. Earth history is also influenced by occasional catastrophes, such as the impact of an asteroid or comet.

3. Earth in the Solar System
 - a. Gravity is the force that keeps planets in orbit around the sun and governs the rest of the motion in the solar system

As a result of their activities in grades 9-12, students should develop:

1. Understanding of energy in the Earth System
 - a. The outward transfer of earth's internal heat drives convection circulation in the mantle that propels the plates comprising earth's surface across the face of the globe.
2. The Origin and Evolution of the Earth System
 - a. The sun, the earth, and the rest of the solar system formed from a nebular cloud of dust and gas 4.6 billion years ago. The early earth was very different from the planet we live on today.
 - b. Interactions among the solid earth, the oceans, the atmosphere, and organisms have resulted in the ongoing evolution of the earth system. We can observe some changes such as earthquakes and volcanic eruptions on a human time scale, but many processes such as mountain building and plate movements take place over hundreds of millions of years.

- **Content Standard E (Science and Technology)**

As a result of activities in grades 5-8, students should develop:

1. Understanding about science and technology.
 - a. Science and technology are reciprocal.
 - b. Technology provides tools for investigations, inquiry, and analysis.

As a result of activities in grades 9-12, students should develop:

1. Understandings about science and technology.
 - a. Creativity, imagination, and a good knowledge base are all required in the work of science and engineering.
 - b. Science and technology are pursued for different purposes. Scientific inquiry is driven by the desire to understand the natural world, and technological design is driven by the need to meet human needs and solve human problems.

- **Content Standard F (Science in Personal and Social Perspectives)**

As a result of activities in grades 5-8, all students should develop understanding of:

1. Science and technology in society.

As a result of activities in grades 9-12, students should develop an understanding of:

1. Science and technology in local, global, and national challenges.

- **Content Standard G (History and Nature of Science)**

As a result of activities in grades 5-8, students should develop an understanding of:

1. Science as human endeavor.
2. Nature of science.

- a. Scientists formulate and test their explanations of nature using observation, experiments, and theoretical and mathematical models.
 - b. In areas where active research is being pursued and in which there is not a great deal of experimental or observational evidence and understanding, it is normal for scientists to differ with one another about the evidence or theory being considered.
3. History of science
 - a. Many individuals have contributed to the traditions of science.

As a result of activities in grades 9-12, students should develop an understanding of:

1. Science as human endeavor.
 - a. Individuals and teams have contributed and will continue to contribute to the scientific enterprise. Doing science or engineering can be as simple as an individual conducting field studies or as complex as hundreds of people working on a major scientific question or technological problem. Pursuing science as a career or as a hobby can be both fascinating and intellectually rewarding.
 - b. Scientists have ethical traditions. Scientists value peer review, truthful reporting about the methods and outcomes of investigations, and making public the results of work. Violations of such norms do occur, but scientists responsible for such violations are censured by their peers.
Scientists are influenced by societal, cultural, and personal beliefs and ways of viewing the world. Science is not separate from society but rather science is a part of society

Benchmarks for Science Literacy Project 2061

(<http://www.project2061.org/publications/bsl/online/index.php?chapter=4#A3>)

By the end of eighth grade, students should know:

- When similar investigations give different results, the scientific challenge is to judge whether the differences are trivial or significant, and it often takes further studies to decide. 1A/M1a
- Even with similar results, scientists may wait until an investigation has been repeated many times before accepting the results as correct. 1A/M1b
- Scientific knowledge is subject to modification as new information challenges prevailing theories and as a new theory leads to looking at old observations in a new way. 1A/M2
- Some scientific knowledge is very old and yet is still applicable today. 1A/M3
- Scientists differ greatly in what phenomena they study and how they go about their work. 1B/M1a
- Scientific investigations usually involve the collection of relevant data, the use of logical reasoning, and the application of imagination in devising hypotheses and explanations to make sense of the collected data. 1B/M1b

- If more than one variable changes at the same time in an experiment, the outcome of the experiment may not be clearly attributable to any one variable. It may not always be possible to prevent outside variables from influencing an investigation (or even to identify all of the variables). 1B/M2ab
- Collaboration among investigators can often lead to research designs that are able to deal with situations where it is not possible to control all of the variables. 1B/M2c
- What people expect to observe often affects what they actually do observe. Strong beliefs about what should happen in particular circumstances can prevent them from detecting other results. 1B/M3ab
- Scientists know about the danger of prior expectations to objectivity and take steps to try and avoid it when designing investigations and examining data. One safeguard is to have different investigators conduct independent studies of the same questions. 1B/M3cd
- Computers have become invaluable in science, mathematics, and technology because they speed up and extend people's ability to collect, store, compile, and analyze data; prepare research reports; and share data and ideas with investigators all over the world. 1C/M6
- In earlier times, the accumulated information and techniques of each generation of workers were taught on the job directly to the next generation of workers. Today, the knowledge base for technology can be found as well in libraries of print and electronic resources and is often taught in the classroom. 3A/M1
- Technology is essential to science for such purposes as access to outer space and other remote locations, sample collection and treatment, measurement, data collection and storage, computation, and communication of information. 3A/M2
- Societies influence what aspects of technology are developed and how these are used. People control technology (as well as science) and are responsible for its effects. 3C/M7
- Nine planets of very different size, composition, and surface features move around the sun in nearly circular orbits. Some planets have a variety of moons and even flat rings of rock and ice particles orbiting around them. Some of these planets and moons show evidence of geologic activity. The earth is orbited by one moon, many artificial satellites, and debris. 4A/M3
- Many chunks of rock orbit the sun. Those that meet the earth glow and disintegrate from friction as they plunge through the atmosphere—and sometimes impact the ground. Other chunks of rock mixed with ice have long, off-center orbits that carry them close to the sun, where the sun's radiation (of light and particles) boils off frozen materials from their surfaces and pushes it into a long, illuminated tail. 4A/M4*Some distant galaxies are so far away that their light takes several billion years to reach the earth. People on earth, therefore, see them as they were that long ago in the past. 4A/M3
- The earth is mostly rock. Three-fourths of the earth's surface is covered by a relatively thin layer of water (some of it frozen), and the entire planet is surrounded by a relatively thin layer of air. 4B/M2ab

- Earth is the only body in the solar system that appears able to support life. The other planets have compositions and conditions very different from the earth's. 4B/M2cd
- The moon's orbit around the earth once in about 28 days changes what part of the moon is lighted by the sun and how much of that part can be seen from the earth- the phases of the moon. 4B/M5
- Some material resources are very rare and some exist in great quantities. The ability to obtain and process resources depends on where they are located and the form they are in. As resources are depleted, they may become more difficult to obtain. 4B/M10ab
- The atmosphere is a mixture of nitrogen, oxygen, and trace amounts of water vapor, carbon dioxide, and other gases. 4B/M15** (NSES)
- The interior of the earth is hot. Heat flow and movement of material within the earth cause earthquakes and volcanic eruptions and create mountains and ocean basins. Gas and dust from large volcanoes can change the atmosphere. 4C/M1
- Some changes in the earth's surface are abrupt (such as earthquakes and volcanic eruptions) while other changes happen very slowly (such as uplift and wearing down of mountains). 4C/M2a
- The earth's surface is shaped in part by the motion of water (including ice) and wind over very long times, which acts to level mountain ranges. Rivers and glacial ice carry off soil and break down rock, eventually depositing the material in sediments or carrying it in solution to the sea. 4C/M2b*
- Sediments of sand and smaller particles (sometimes containing the remains of organisms) are gradually buried and are cemented together by dissolved minerals to form solid rock again. 4C/M3
- Sedimentary rock buried deep enough may be re-formed by pressure and heat, perhaps melting and recrystallizing into different kinds of rock. These re-formed rock layers may be forced up again to become land surface and even mountains. Subsequently, this new rock too will erode. Rock bears evidence of the minerals, temperatures, and forces that created it. 4C/M4
- Thousands of layers of sedimentary rock confirm the long history of the changing surface of the earth and the changing life forms whose remains are found in successive layers. The youngest layers are not always found on top, because of folding, breaking, and uplift of layers. 4C/M5
- Although weathered rock is the basic component of soil, the composition and texture of soil and its fertility and resistance to erosion are greatly influenced by plant roots and debris, bacteria, fungi, worms, insects, rodents, and other organisms. 4C/M6
- There are a variety of different land forms on the earth's surface (such as coastlines, rivers, mountains, deltas, and canyons). 4C/M8** (BSL)
- The earth first formed in a molten state and then the surface cooled into solid rock. 4C/M10** (ASL)

- The outer layer of the earth—including both the continents and the ocean basins—consists of separate plates. 4C/M11** (BSL)
- The earth's plates sit on a dense, hot, somewhat melted layer of the earth. The plates move very slowly, pressing against one another in some places and pulling apart in other places, sometimes scraping alongside each other as they do. Mountains form as two continental plates, or an ocean plate and a continental plate, press together. 4C/M12** (BSL)
- There are worldwide patterns to major geological events (such as earthquakes, volcanic eruptions, and mountain building) that coincide with plate boundaries. 4C/M13** (BSL)

By the end of twelfth grade, students should know:

- Science is based on the assumption that the universe is a vast single system in which the basic rules are everywhere the same and that the things and events in the universe occur in consistent patterns that are comprehensible through careful, systematic study. 1A/H1
- From time to time, major shifts occur in the scientific view of how things work. More often, however, the changes that take place in the body of scientific knowledge are small modifications of prior knowledge. Continuity and change are persistent features of science. 1A/H2
- No matter how well one theory fits observations, a new theory might fit them just as well or better, or might fit a wider range of observations. 1A/H3a
- In science, the testing, revising, and occasional discarding of theories, new and old, never ends. This ongoing process leads to a better understanding of how things work in the world but not to absolute truth. 1A/H3bc
- In matters that can be investigated in a scientific way, evidence for the value of a scientific approach is given by the improving ability of scientists to offer reliable explanations and make accurate predictions. 1A/H3d
- Investigations are conducted for different reasons, including exploring new phenomena, to check on previous results, to test how well a theory predicts, and to compare theories. 1B/H1
- Hypotheses are widely used in science for choosing what data to pay attention to and what additional data to seek, and for guiding the interpretation of the data (both new and previously available). 1B/H2
- Sometimes, scientists can control conditions in order to obtain evidence. When that is not possible, practical, or ethical, they try to observe as wide a range of natural occurrences as possible to discern patterns. 1B/H3
- There are different traditions in science about what is investigated and how, but they all share a commitment to the use of logical arguments based on empirical evidence. 1B/H4
- In the long run, theories are judged by the range of observations they explain, how well they explain observations, and how useful they are in making accurate predictions. 1B/H6b

- Progress in science and invention depends heavily on what else is happening in society. 1C/H3a
- On the basis of scientific evidence, the universe is estimated to be over ten billion years old. The current theory is that its entire contents expanded explosively from a hot, dense, chaotic mass. 4A/H2ab
- Increasingly sophisticated technology is used to learn about the universe. Visual, radio, and X-ray telescopes collect information from across the entire spectrum of electromagnetic waves; computers handle data and complicated computations to interpret them; space probes send back data and materials from remote parts of the solar system; and accelerators give subatomic particles energies that simulate conditions in the stars and in the early history of the universe before stars formed. 4A/H3
- Mathematical models and computer simulations are used in studying evidence from many sources in order to form a scientific account of the universe. 4A/H4
- Technological problems and advances often create a demand for new scientific knowledge, and new technologies make it possible for scientists to extend their research in new ways or to undertake entirely new lines of research. The very availability of new technology itself often sparks scientific advances. 3A/H1
- Mathematics, creativity, logic, and originality are all needed to improve technology. 3A/H2
- One way science affects society is by stimulating and satisfying people's curiosity and enlarging or challenging their views of what the world is like. 3A/H3b
- The human ability to influence the course of history comes from its capacity for generating knowledge and developing new technologies—and for communicating ideas to others. 3C/H6** (BSL)
- As the earth and other planets formed, the heavier elements fell to their centers. On planets close to the sun (Mercury, Venus, Earth, and Mars), the lightest elements were mostly blown or boiled away by radiation from the newly formed sun; on the outer planets (Jupiter, Saturn, Uranus, Neptune, and Pluto) the lighter elements still surround them as deep atmospheres of gas or as frozen solid layers. 4A/H5** (SFAA)
- Our solar system coalesced out of a giant cloud of gas and debris left in the wake of exploding stars about five billion years ago. Everything in and on the earth, including living organisms, is made of this material. 4A/H6** (SFAA)
- The earth has many natural resources of great importance to human life. Some are readily renewable, some are renewable only at great cost, and some are not renewable at all. 4B/H8
- The formation, weathering, sedimentation, and reformation of rock constitute a continuing "rock cycle" in which the total amount of material stays the same as its forms change. 4C/H2
- The outward transfer of the earth's internal heat causes regions of different temperatures and densities. The action of a gravitational force on regions of different densities causes

the rise and fall of material between the earth's surface and interior, which is responsible for the movement of plates. 4C/H3

- Earthquakes often occur along the boundaries between colliding plates, and molten rock from below creates pressure that is released by volcanic eruptions, helping to build up mountains. Under the ocean basins, molten rock may well up between separating plates to create new ocean floor. Volcanic activity along the ocean floor may form undersea mountains, which can thrust above the ocean's surface to become islands. 4C/H5
- Scientific evidence indicates that some rock layers are several billion years old. 4C/H6** (BSL)

Unit Overview

Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Introduction – Why the Moon?	Origins of Moon and Earth	Differentiation	Volcanism, Lava Flows & Maria	Craters & Boulders	Highlands	Regolith
Standards (See code key below) MS-ESS1-3 & 4 SEP 1, 2, 4, 7 CC 1, 6, 7	MS-ESS1-2 & 4 MS-ESS2-1 SEP 1, 3, 4 CC 1, 2, 6	MS-ESS1-3 & 4 MS-ESS2-1 MS-ESS3-1 SEP 2, 4 CC 1, 2, 5, 6	MS-ESS1-3 & 4 MS-ESS2-2 SEP 2 CC 2, 4	MS-ESS1-3 & 4 MS-ESS2-2 SEP 1, 2, 3, 4, 5 CC 2, 3, 4	MS-ESS1-3 & 4 MS-ESS2-2 & 3 SEP 1, 2, 6 CC 2, 4	MS-ESS1-3 & 4 MS-ESS2-2 SEP 8 CC 2, 3, 4
Engage Compare lunar and Earth features by classifying pictures	Engage Video: <i>Origin of the Moon</i>	Engage Density demonstration (alcohol, water, oil)	Engage Video: <i>National Geographic Forces of Nature – Volcanoes 101</i>	Engage Display of pictures of craters on Earth and Moon	Engage <i>Demonstrating Plate Tectonics With a Box</i> ; ask students how it happened on the Moon	Engage Video: <i>Two New NASA LRO Videos: See Moon's Evolution</i> ; end with explanation that dust will end up as regolith
Explore Construct Venn diagram of Earth/Moon in Moon Journal	Explore <i>Reaping Rocks</i>	Explore <i>Differentiation</i>	Explore <i>Lava Layering</i> OR <i>Clay Lava Flows</i>	Explore <i>Impact Craters</i>	Explore <i>Lunar Surface</i> (mapping all the Moon's features)	Explore <i>Regolith Formation</i> OR <i>Making Regolith</i>
Explain <u>Vocabulary</u> : geologist, terrain <u>Concept</u> : features of the Moon have their equivalents on	Explain <u>Vocabulary</u> : mineral, rock, igneous, metamorphic, sedimentary <u>Concept</u> :	Explain <u>Vocabulary</u> : differentiation, density, magma ocean <u>Concept</u> : density of materials	Explain <u>Vocabulary</u> : eruption, source, stratigraphy, lava flows, channels and levees, pressure	Explain <u>Vocabulary</u> : impact, impactor, ejecta, rays, rim, wall, central uplift <u>Concept</u> :	Explain <u>Vocabulary</u> : highlands, rill, earthquake, moonquake <u>Concept</u> : Earth and Moon have	Explain <u>Vocabulary</u> : regolith, meteoritic bombardment, weathering, erosion

	and minerals; geologic classification systems	the crust; some minerals are resources for people	creates geological structures as it flows across planetary landscapes	the Moon; craters on Earth weather more quickly	processes; return to opening question to get student predictions	formed by weathering; Moon's regolith by meteors
Evaluate Pretest; Start a Moon Journal	Evaluate Completed lab sheet and questions	Evaluate Completed lab sheet and questions	Evaluate Vocabulary quiz	Evaluate Completed data table and questions	Evaluate Concept quiz	Evaluate Completed lab sheet and questions
Elaborate Students find pictures of geologic features on Earth, describe processes that formed them	Elaborate Article: <i>A New Look at Apollo Samples Supports Ancient Impact Theory</i>	Elaborate Interactive Rock Cycle website	Elaborate Investigate different types of volcanoes	Elaborate Debate the possible outcomes of a meteorite hitting the Earth or the Moon	Elaborate <i>Lunar Landing Sites</i>	Elaborate <i>Moon Archeology</i>
Technology Link Building telescopes	Technology Link <i>Launch It</i> activity	Technology Link <i>Touchdown</i> activity	Technology Link N/A	Technology Link <i>Heavy Lifting</i> activity	Technology Link <i>On Target</i> activity	Technology Link <i>Moon Archeology</i>
Links <u>Language Arts</u> Research legends about the "Man in the Moon"	Links <u>Language Arts</u> <i>Teaching With Stories and Symbols</i>	Links <u>Math</u> Construct a table of percentages of minerals in the Earth's and/or Moon's crust	Links <u>Social Studies</u> Research volcanoes in history and their effects on human cultures	Links <u>Math</u> Use craters made in class to calculate pi (π).	Links <u>Geography</u> – Compare map of Earth's mountain ranges to Moon mountain ranges	Links <u>Art</u> – Make a poster illustrating the lunar surface

Days 8 and 9	Days 10 and 11	Day 12	Day 13	Day 14	Day 15
<i>Moon Mappers</i> site introduction	Anomalies	Exploration	Lunar site practice	Review	Evaluation
MS-ESS1-3 & 4 MS-ESS2-2 SEP 3, 4, 8 CC 1, 2, 7	MS-ESS1-2, 3, & 4 MS-ESS2-2 SEP 7 CC 1, 2, 7	SEP 3, 4, 6, 8	SEP 3, 4, 8 CC 1, 2, 7	All standards covered in unit	All standards covered in unit
Engage “Welcome to CosmoQuest” tour of home page	Engage Moon Illusion discrepant event	Engage Video of Apollo 11 landing	Engage Review procedures for crater marking	Engage Preview of material to be tested	Engage Preparation for test
Explore Lunar Surface Age activity; Moon mapping tutorial	Explore <i>Moon Anomalies</i> ; students use Moon Journals for additional information to support their ideas	Explore <i>Apollo Landing Sites</i>	Explore Students identify and map craters at the <i>Moon Mappers</i> web site	Explore none	Explore none
Explain Individual craters have characteristics dependent on the history of their formation; those characteristics give clues to their relative age and processes that formed planetary surfaces	Explain Teams present their hypotheses for class discussions	Explain Vocabulary: latitude, longitude, Sea of Tranquility, Ocean of Storms, Sea of Serenity <u>Concept</u> : Apollo landing sites were chosen for their geologic interest and accessibility	Explain none	Explain Review game; explain concepts as necessary	Explain none
Evaluate	Evaluate	Evaluate	Evaluate	Evaluate	Evaluate

Completed lunar surface pictures; number of mapped craters at <i>Moon Mappers</i> website	Class presentations	Completed lab sheet	Number of craters mapped by each S	none	Test
Elaborate Students begin identifying craters at <i>Moon Mappers</i> web site	Elaborate Explore similar anomalies on Earth	Elaborate Build a <i>Lunar Prospector</i> model	Elaborate Students identify craters at <i>Moon Mappers</i> web site on their own	Elaborate none	Elaborate <i>Lunar Ice Cream</i>
Technology Link Moon Mapping online technology	Technology Link N/A	Technology Link <i>Lunar Roving Vehicles</i> or <i>Roving on the Moon</i>	Technology Link Moon Mapping online technology	Technology Link N/A	Technology Link <i>Lunar Ice Cream</i>
Links Social Studies – Research the history of people who have mapped the Moon Math – Graph the frequencies of the diameters of craters.	Links Language Arts – Write a short story about a Moon mystery	Links Social Studies – View video footage of lunar landings; write an eye-witness newspaper article about the landing	Links Multidisciplinary - Use internet resources to create a power point presentation comparing lunar and Earth surface features.	Links none	Links none

**Key to Standards:*

MS-ESS = Middle School Earth and Space Standards

SEP = NGSS Science and Engineering Practices

1. Asking questions and defining problems
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data

CC = Crosscutting Concepts

1. Patterns
2. Cause and Effect: Mechanism and Prediction
3. Scale, Proportion, and Quantity

5. Using mathematical and computational thinking

6. Constructing explanations and designing solutions

7. Engaging in argument from evidence

8. Obtaining, evaluating and communicating information

4. Systems and System Models

5. Energy and Matter: Flows, Cycles, and Conservation

6. Structure and Function

7. Stability and Change

Instructor's Guide

Materials List

The items listed should be standard in most science classrooms or easily obtained. Please check the references in the day's lesson plans for the quantities suggested and adjust to fit the size of your classroom.

Lesson 1

- 6 sets of 10 black/white pictures of Moon and Earth**
- Large paper for Venn diagrams
- Moon journal for each student
- Resources (magazines, books, online) for explore activity and researching legends about the Moon

Lesson 2

- Extra rock samples for students who forgot theirs
- Empty egg cartons (or boxes or trays)
- Hand lenses and/or stereomicroscope
- Handouts: "Moon ABCs Fact Sheet," My Own Rock Chart**
- "A New Look at Apollo Samples" article for elaborate activity**
- "Teaching with Stories and Symbols" website for interdisciplinary activity**

Lesson 3

- Food color
- Oil
- Alcohol
- Water
- Large glass jar or beaker
- Pennies
- Sand
- Toothpicks
- Beaker for each team
- Handouts: "Differentiation"***
- Information on minerals in Earth's and Moon's crust for interdisciplinary activity

Lesson 4

- For "Lava Layering"
 - Handouts**
 - Paper cups
 - Cookie sheets
 - Tape
 - Tablespoon
 - Baking soda
 - Measuring cup

- Vinegar
 - Clay
 - Knife
- OR for “Clay Lava Flows”
 - Handouts**
 - Clay mixture
 - Bucket
 - Wire whisk
 - Plexiglas
 - Protractor
 - String
 - Stopwatch
 - Tape measure or ruler
- Data tables
- Resource materials to investigate volcanoes for elaborate activity

Lesson 5

- Pan
- Flour, baking soda, corn meal, or sand
- Dry tempera paint **NOTE: Dry tempera paint is mentioned in the NASA activity, but it is difficult to work with and is an inhalation hazard. It is recommended that cocoa or a colored drink mix be used instead.**
- Sieve
- Balance
- Marbles
- Meter stick
- Ruler with center depression
- Protractor
- Graph paper
- Data charts for “Impact Craters” activity**

Lesson 6

- Shoe box
- Paper strips
- Lunar map
- Clay, or plaster of Paris
- Sculpting tools
- Toothpicks
- Construction paper
- Moon pictures (can use those from Lesson 8)
- Handouts: “Lunar Surface”**
- Scrap supplies to make lunar vehicles in elaborate activity

- Maps of Earth and Moon mountain ranges for interdisciplinary activity

Lesson 7

- For “Regolith Formation” activity:
 - White and wheat breads
 - Pan
 - Sand paper
 - Ice cube tray
 - Fist-sized rock
- OR for “Making Regolith” activity:
 - Hand lenses
 - Boxes with lids
 - Cinnamon graham crackers
 - Powdered sugar
 - Mini-donuts
 - Newspapers
 - Index cards
 - Clear tape
 - Strainers
 - Scissors
 - Hole punch
 - Markers
 - Safety goggles
- For “Moon Archeology” elaborate activity:
 - Cookies
 - Probing tools
- Poster paper and creative supplies for interdisciplinary activity

Lesson 8/9

- Black and white pictures of lunar surface to map**
- Markers
- Tape
- Poster board
- Colored acetate sheets
- Computers w/internet access

Lesson 10/11

- Moon maps
- Information on Moon
- Art supplies
- Supplies for chosen discrepant event
- Handouts: “Moon Anomalies”**

Lesson 12

- Lunar maps with latitude and longitude (available online through NASA)
- Moon globe (available through most school supply stores)
- Handouts: “Apollo Landing Sites Chart”**
- Computers w/internet access

Lesson 13

- Computers w/internet access

Lessons 14/15

- Review game, if used
- Handout: post test**

**Items that CosmoQuest provides to teachers online at <http://cosmoquest.org/x/educatorszone/terraluna-connecting-earth-and-moon/> or as links embedded in this pdf.

Instructor's Guide

Vocabulary

Apollo Program: a spaceflight effort carried out by NASA that landed the first humans on the Earth's moon

Central Uplift: mountains in the center of larger craters that were formed from the large changes in pressure during the impact event

Channels and levees (\ 'cha-n³l\ , \ 'le-vē; lə-'vē, -'vā\): refers to furrows of lava flows situated between levees, which are the outer part of the flow

Crater chains: circular depressions that may appear in straight or curved paths. In curved paths they are probably incompletely formed rilles. In straight paths, they are probably from rocks strewn out during an impact event.

Density: the degree of compactness of a substance; mass per unit of volume

Differentiation (\dɪf-ə-ren(t)-shē-'ā-shən\): the processes that result in the separation of minerals during the cooling of magma

Earthquake (\ 'ərth- ,kwāk\): shaking and vibration at the surface of the Earth resulting from underground movement along a fault plane or from volcanic activity

Ejecta (\i-'jek-tə\): blanket of material surrounding a crater that was excavated during an impact event

Erosion (\i-'rō-zhən\): wearing away of the surface of a planetary body as water, wind, or other natural agents move materials from one place to another

Eruption (\i-'rəp-shən\): the occurrence of a discharge of steam and volcanic material; it may be sudden and violent, or slow and quiet

Highlands (\ 'hī-ləndz\): light colored, mountainous areas on the surface of the Moon

Igneous (\ 'ig-nē-əs\): rock formed from cooled and hardened magma

Impact: striking of one body against another, in a forceful manner

Impactor: an object that collides with another body

Latitude (\ 'la-tə- ,tūd, - ,tyüd\): an imaginary line around the Earth parallel to the equator

Lava flows: streams of molten material coming from a volcanic cone

Longitude (\ 'län-jə- ,tūd, - ,tyüd\): an imaginary great circle on the surface of the Earth passing through the north and south poles at right angles to the equator

Lunar rover: battery-powered four-wheeled vehicle used on the Moon

Magma (\ 'mag-mə\): molten rock below the surface of a planet or moon

Magma ocean: layer of magma, hundreds of kilometers thick, thought to have covered the Moon 4.5 billion years ago

Maria (\mahr-ee-uh\): large, dark areas on the surface of the Moon (singular = mare)

Metamorphic (\,me-tə-'môr-fik\): rock formed from pre-existing rocks as a result of intense heat, pressure, or chemical processes

Meteoritic bombardment: meteors striking a planetary surface

Mineral: naturally formed solid with a crystalline structure and a specific chemical makeup

Moonquake: vibrations on the Moon similar to an earthquake, but usually of lower magnitude

Mountains: lighter colored regions of the Moon commonly called highlands

Ocean of Storms: the largest of the dark plains (maria) on the surface of the Moon, in the second and third quadrants

Planetary geologist: scientist who studies the formation, structure, history, and processes that change Earth and other planetary bodies

Pressure ridges: a seismic feature resulting from transverse pressure and shortening of the land surface

Ray: bright streak extending a great distance from a crater

Regolith (\ 're-gə-, lith\): loose, fragmented material on the Moon's surface

Rilles (\ 'ril z\): long, narrow, straight or sinuous trenches or valleys observed on the Moon's surface

Rock: solid material made of minerals forming part of the surface of the Earth and other planetary objects

Sea of Serenity (\sə-'re-nə-tē\): a lunar mare near the sites of two manned lunar missions

Sea of Tranquility (træŋ'kwil·r·tī\): landing site of Apollo 11

Sedimentary (\,se-də-'men-tə-rē, -'men-trē\): type of rock formed from hardened deposits of sediments

Stratigraphy (\strə-'ti-grə-fē\): the study of rock layering

Terrain: an area of land or ground with all of its natural components

Weathering: processes that cause rocks to fragment, crack, crumble or decay

Instructor's Guide

Featured Links

CosmoQuest

CosmoQuest home – <http://cosmoquest.org/>

Moon Mappers – <http://cosmoquest.org/mappers/moon/>

CosmoQuest Educators' Zone - <http://cosmoquest.org/x/educatorszone>

CosmoQuest Community – <http://cosmoquest.org/Community>

CosmoQuest Academy (online courses) – <http://cosmoquest.org/x/cosmoacademy>

Teaching

BSCS 5E Inquiry Teaching Model – <http://www.bsos.org/bsos-5e-instructional-model>

Next Generation Science Standards – <http://www.nextgenscience.org/>

Lesson 1

Pictures of Earth and Moon features (be sure to print in black and white)

All: https://www.dropbox.com/s/prtv9jlatws3zlg/bw_earthnoteearth.pptx.pdf

Earth:

E1. Vredefort Dome (South Africa)

http://upload.wikimedia.org/wikipedia/commons/c/c3/Vredefort_crater.jpg

E2. Nevado del Ruiz (Columbia)

http://upload.wikimedia.org/wikipedia/commons/0/0f/Nevado_del_Ruiz_-_radar_image_from_space.jpg

E3. Barringer Crater (United States)

<http://ut-images.s3.amazonaws.com/wp-content/uploads/2008/11/barringer-meteorite-crater.jpg>

E4. Volcanoes (Mexico)

http://www.nasa.gov/images/content/114750main_image_feature_328_ys_4.jpg

E5. Erosion (Libya)

http://www.nasa.gov/images/content/285297main_iss017e013789_high.jpg

E6. Tirari Desert (Australia)

http://upload.wikimedia.org/wikipedia/commons/1/12/Tirari_Desert_-_NASA_-_satellite_2006.jpg

E7. Manicouagan Reservoir (Canada)

<https://dl.dropbox.com/u/19254794/TERRALUNA%20manicouagan-reservoir.jpg>

Moon:

M1. Lunar rille

http://www.nasa.gov/images/content/463898main2_LRO_Rille_670.jpg

M2: Lunar graben

http://www.nasa.gov/images/content/623732main_video_graben_image_lgweb.jpg

M3. Lunar crater (Tycho)

http://upload.wikimedia.org/wikipedia/commons/f/f8/Tycho_crater_on_the_Moon.jpg

M4: Lunar crater central peak (Tycho)

<http://apod.nasa.gov/apod/ap110706.html>

M5: Lunar mare (Orientale)

http://en.wikipedia.org/wiki/File:Orientale_lro.jpg

M6: Lunar ejecta from young crater

http://www.nasa.gov/images/content/424832main_murchison_lg.jpg

M7: Lunar volcanic pit crater

http://lroc.sese.asu.edu/news/uploads/LROCiotw/M131488521RE-2_thumb.png

Building telescopes—

http://www.nasa.gov/audience/foreducators/informal/features/F_Build_a_Telescope_prt.htm

<http://www.universetoday.com/17366/build-a-telescope/>

Lesson 2

Origins of the Moon video –

<http://www.neok12.com/php/watch.php?v=zX5f0066004258764170407f&t=Moon>

Exploring the Moon NASA Teachers Guide –

<http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Exploring.the.Moon.html>

Reaping Rocks NASA activity –

http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Reaping_Rocks.html

Article for Elaborate activity –

<http://www.universetoday.com/95386/a-new-look-at-apollo-samples-supports-ancient-impact-theory/>

Article for Interdisciplinary Link activity –

<http://lunar.ksc.nasa.gov/education/spaceday/activity/pdf/teachi.pdf>

On the Moon Educator Guide for technology activity—

http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/On_the_Moon_Guide.html

Lesson 3

Differentiation NASA activity –

<http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Differentiation.html>

Interactive Rock Cycle for Elaborate activity –

<http://www.learner.org/interactives/rockcycle/types2.html>

On the Moon Educator Guide for technology activity—

http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/On_the_Moon_Guide.html

Lesson 4

National Geographic video *Volcanoes 101* –

<http://video.nationalgeographic.com/video/kids/forces-ofnature-kids/volcanoes-101-kids/>

Clay Lava Flows NASA activity –

http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Clay_Lava_Flows.html

Lava Layering NASA activity –

http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Lava_Layering.html

Lesson 5

Impact Craters activity –

http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Impact_Craters.html

Make a Crater activity – <http://lunar.arc.nasa.gov/education/activities/active15a.htm>

Pictures of Earth craters –

http://apod.nasa.gov/apod/image/9711/azcrater_lpi_big.jpg

<http://upload.wikimedia.org/wikipedia/commons/1/1f/Manicouagan-EO.JPG>

Pictures of Moon craters –

http://lroc.sese.asu.edu/news/uploads/LROCiotw/M131488521RE-2_thumb.png

http://upload.wikimedia.org/wikipedia/commons/f/f8/Tycho_crater_on_the_Moon.jpg
On the Moon Educator Guide for technology activity—
http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/On_the_Moon_Guide.html

Lesson 6

Plate Tectonics in a Box demonstration –

http://volcano.oregonstate.edu/vwdocs/vwlessons/activities/p_number5.html

Animated plate tectonics –

http://www.knowitall.org/nasa/simulations/plate_movements/index.html

Lunar Surface activity –

http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Lunar_Surface.html

Lunar Landing Sites Elaborate activity –

http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Lunar_Landing.html

On the Moon Educator Guide for technology activity—

http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/On_the_Moon_Guide.html

Lesson 7

Two New NASA LRO Videos: See Moon's Evolution, Take a Tour

http://www.nasa.gov/mission_pages/LRO/news/vid-tour.html

Information on Moon's surface –

<http://www.astrosociety.org/education/publications/tnl/13/13.html>

Regolith Formation activity –

http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Regolith_Formation.html

Making Regolith activity –

http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Making_Regolith_Activity.html

Moon Archeology for Elaborate activity –

<http://lunar.arc.nasa.gov/education/activities/active5a.htm>

Lesson 8

Lunar Craters Through 8" Telescope – <http://www.youtube.com/watch?v=k4YLMASou78>

Lunar Moon Crater Copernicus Close Up – <http://www.youtube.com/watch?v=AYa1LyVWiaQ>

CosmoQuest home – <http://cosmoquest.org/>

Moon Mappers – <http://cosmoquest.org/mappers/moon/>

Lesson 9

CosmoQuest home – <http://cosmoquest.org/>

Moon Mappers – <http://cosmoquest.org/mappers/moon/>

Lunar Roving Vehicle –

http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Lunar_Roving.html

Lesson 10/11

Moon Illusion – <http://news.discovery.com/space/moon-horizon-optical-illusion.html>

Moon Anomalies –

http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Moon_Anomalies.html

Lesson 12

Apollo Moon Landing – <http://video.google.com/videoplay?docid=1416393771637021814>)

Apollo Landing Sites –

http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Apollo_Landing.html

Map of Apollo Landing sites –

http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Nearside_Apollo.html

Lunar Prospector model - <http://lunar.arc.nasa.gov/education/activities/active1a.htm>

Lesson 13

CosmoQuest Moon Mappers – <http://cosmoquest.org/mappers/moon/>

Lesson 14 - none

Lesson 15

Lunar Ice Cream – <http://lunar.arc.nasa.gov/education/activities/active12a.htm>

Other Moon Links

Lunar Prospector homepage – <http://lunar.arc.nasa.gov/education/activities/index.htm>

On-line Planisphere – <http://science.hq.nasa.gov/skyspy/noaccess.html>

NOTE: All linked pictures are in the public domain or licensed under Creative Commons and are free for educational use.

Instructor's Guide

Day One – Introduction: Why the Moon?

Objective: Students will compare and contrast surface features of the Earth and Moon.

Materials: Six sets of ten black and white pictures of the Earth and Moon surfaces---five representing each surface, large sheets of paper for Venn diagrams

Engage: Earth or Not Earth?

Compare Moon and Earth features by classifying pictures.

- Teams are given 10 pictures – five of black-and-white Earth features, five of Moon features.
- Ask: Which are pictures of the Moon, which are pictures of the Earth, as seen from above?
- Teams separate pictures into Moon group and Earth group, *discussing their reasoning*.
- Conduct whole group discussion: What clues did you use to identify the picture

Explore: Construct Venn diagram of Earth/Moon.

- Distribute one large piece of paper to each team.
- Teams draw a Venn diagram to show similarities and differences between the geologic features and history of the Earth and Moon.
- Students copy their team's diagram in their Moon Journals.

Explain:

Vocabulary: Terrain, planetary geologist

Concepts

- Features of the Moon have their equivalents on Earth; the form of the features result from similarities and differences between geologic processes.
- Scientists study the Moon to learn more about the processes that shape it. Knowledge gained can be applied to similar structures on Earth as well as other planetary bodies.
- Students copy vocabulary, definitions, and concepts into their Moon Journals.

Evaluate: Check completion of Moon Journals.

Elaborate:

Have each student find a picture of a geologic feature on Earth and tape it into a journal page. Students then write a paragraph to explain the processes that might have formed the feature and if this feature might also exist on the Moon.

Technology Links:

How did people first learn about the features on the surface of the Moon? Students can find out by building and using their own telescopes. Several simple homemade telescopes can be found at http://www.nasa.gov/audience/foreducators/informal/features/F_Build_a_Telescope_prt.htm and <http://www.universetoday.com/17366/build-a-telescope/>. You may choose to ask students to look at the Moon with their new telescopes, binoculars, or just naked eye and record what they see in their journals for the activity on day six.

Interdisciplinary Link:

Link to Language Arts - Research legends about “The Man in the Moon” and other lunar legends

****REMINDER:** Ask students to bring three or more natural rock samples, (not brick, concrete, or other manufactured rocks), from home for tomorrow's class.

Instructor's Guide

Day Two – Origins of Moon and Earth

Objective: Students will make predictions about the origin of lunar rocks by collecting, describing, and classifying neighborhood rocks.

Materials: Rocks, empty egg carton, box or collection tray, labels, magnifying lens or stereomicroscope, “Moon ABCs Fact Sheet” and “My Own Rock Chart” lab sheet (both found in “Reaping Rocks” activity link below)

Engage: Video: Origin of the Moon

<http://www.neok12.com/php/watch.php?v=zX5f0066004258764170407f&t=Moon>

Explore: Use the directions in the *Reaping Rocks* activity to guide students through the description and classification of rock samples

- If students forgot to bring rocks from home, the beginning of class could include a brief walk around the school site to collect rocks.
- Teams of students can work together to classify their rocks and complete the lab sheet.

http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Reaping_Rocks.html

(This activity is part of the *Exploring the Moon* Teachers Guide at

<http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Exploring.the.Moon.html>)

Explain:

Vocabulary

- mineral, rock, igneous, metamorphic, sedimentary
(See the teachers guide or the glossary in teacher resources for definitions.)
- Students copy vocabulary and definitions in their Moon Journals.

Concepts

- Rocks are made up of minerals; minerals are naturally formed solids with a specific chemical makeup.
- Rocks are classified as igneous, metamorphic, or sedimentary, based on the way they were formed.
- Students should note the difference between rocks and minerals in their journals.

Evaluate: Students hand in completed lab sheets and questions.

Elaborate: Have students read the article: *A New Look at Apollo Samples Supports Ancient Impact Theory*, Universe Today, May 24, 2012 at

<http://www.universetoday.com/95386/a-new-look-at-apollo-samples-supports-ancient-impact-theory/>

Have students write a summary paragraph in their journals.

Invite students to start their own rock collections.

Technology Link: *Launch It* air-powered rocket design challenge in the *On the Moon Educator Guide* at

http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/On_the_Moon_Guide.html

Add a design to increase students' interest in studying the Moon. In order to study Moon rocks, scientists and engineers had to design spacecraft capable of leaving Earth's gravity and landing safely on the Moon.

Interdisciplinary Link: Link to Language Arts – Use *Teaching With Stories and Symbols* at

<http://lunar.ksc.nasa.gov/education/spaceday/activity/pdf/teachi.pdf> to show students that astronomy was important to ancient cultures and other present day cultures.

Instructor's Guide

Day Three - Differentiation

Objective:

Students will see how minerals separate from each other during the cooling and remelting of magma

Materials:

food color dye, oil, alcohol, water, and large glass jar or beaker for opening demonstration; pennies, sand, toothpicks, bowl, transparent container or beaker for each team

Engage:

Density demonstration

- Use food color to dye equal amounts of alcohol, water, and oil. Carefully pour the liquids, one at a time, into a glass jar.
- Have students write their observations of the separation of layers, as well as possible explanations, in their journals.
- Discuss briefly: What does this have to do with the Earth and Moon?

Explore:

Use the directions in the *Differentiation* activity to guide students through a demonstration of separation of materials of various densities and generate answers to questions about differentiation.

<http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Differentiation.html>

(This activity is part of the *Exploring the Moon* Teachers Guide at

<http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Exploring.the.Moon.html>)

Explain:

Vocabulary

- differentiation, density, magma
- Students copy vocabulary, definitions, and concepts into their Moon Journals.

Concepts

- As magma cools, minerals form and separate based on their densities.
- The density of materials determines where they are found in the crust.
- Mineral deposits found in the Earth's crust are natural resources.

Evaluate:

Students hand in completed lab sheets and questions.

Elaborate:

Invite students to explore the Interactive Rock Cycle website at

<http://www.learner.org/interactives/rockcycle/types2.html>

Technology Link:

Touchdown activity in *On the Moon Educator Guide* at

http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/On_the_Moon_Guide.html

This activity continues the simulation of designing technology to take astronauts to the Moon. The importance of being able to land a spacecraft on rocky ground can link to today's lesson.

Interdisciplinary Link:

Link to Math - Construct a table of percentage of minerals in the Earth's and/or Moon's crust

Instructor's Guide

Day Four – Volcanism, Lava Flows, and Maria

Objective:

Students will learn about stratigraphy and lava layering and understand some of the geological processes and resulting structures that form as a result of lava flowing over planetary surfaces.

Materials: small paper cups, cafeteria tray or cookie sheet, tape, tablespoon, baking soda, measuring cup, vinegar, four different colors of food coloring, playdough or clay, and plastic knife for *Lava Layering*
OR

Clay mixture, bucket, wire whisk, Plexiglas or other nonporous surface, protractor with plumb line, stop watch, tape measure or ruler, and data tables for *Clay Lava Flows*

Engage:

Video: *National Geographic Forces of Nature – Volcanoes 101*

<http://video.nationalgeographic.com/video/kids/forces-of-nature-kids/volcanoes-101-kids/>

Explore:

Use the directions for *Lava Layering* or *Clay Lava Flows* activities to guide students through the analysis of the characteristics of lava flows.

Lava Layering directs students to trace the edges of vinegar and baking soda to simulate a series of eruptions. In steps six through seven, it may help to have students trace the outline of flow first, dry the tray and affected clay, and then layer the clay to fill the outlined area.

http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Lava_Layering.html

OR

In *Clay Lava Flows*, students use a mud solution to measure flow rates down an incline.

http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Clay_Lava_Flows.html

(These activities are part of the *Exploring the Moon* Teachers Guide at

<http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Exploring.the.Moon.html>)

Explain:

Vocabulary:

- eruption, stratigraphy, lava flows, channels and levees, pressure ridges, mare
- Students copy vocabulary, definitions, and concepts into their Moon Journals.

Concepts:

- Lava creates geological structures as it flows across planetary landscapes.
- Existing geologic features affect lava as it flows.
- The stratigraphy of successive lava flows can give information about past eruptions.

Evaluate:

Give vocabulary quiz to check understanding of terminology used in lessons one through four.

Elaborate:

Have students investigate different types of volcanoes and record their findings in their journals. Students can discuss the types of volcanoes they might see on the Moon.

Interdisciplinary Link:

Link to Social Studies – Students research volcanoes in history and describe their effects on human cultures.

Instructor's Guide

Day Five – Crater and Boulders

Objective:

Students will determine the factors affecting the appearance of impact craters and ejecta. They will learn to differentiate between craters and boulders.

Materials:

Pan, “lunar” surface material (flour, baking soda, sand, corn meal etc.), cocoa powder, sieve or sifter, balance, marbles or other spheres, meter stick, plastic ruler with middle depression, protractor, data chart, graph paper

Engage:

Display pictures of craters on Earth and Moon. (See "Featured Links," p.20.) Ask students to hypothesize how the craters were formed. Is the process the same on Earth as on the Moon? Make sure they give reasons for their hypotheses.

Explore:

Use the directions for *Impact Craters* to have students drop marbles of different masses onto a simulated lunar surface, measure the impact craters, and graph the results. Do NOT use dry tempura paint as the activity suggests. Use cocoa powder or some other powdered drink mix.

<http://lunar.arc.nasa.gov/education/activities/active15a.htm>

(This activity is part of the *Exploring the Moon* Teachers Guide at <http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Exploring.the.Moon.html>)

Explain:

Vocabulary: impact, impactor, ejecta, rays, rim, wall, central uplift

Concept: Impactors (meteors, asteroids, comets) could hit both Earth and the Moon, but Earth's atmosphere prevents many of them from reaching the ground as meteorites or forming craters. The atmosphere also causes craters on Earth to weather more quickly.

Students copy vocabulary, definitions, and concepts into their Moon Journals.

Evaluate:

Completed data table, graph, and questions can be used for the assessment.

Elaborate:

Invite the students to form teams to debate the possible outcomes of a large meteorite hitting the Earth or the Moon today. Encourage them to think beyond the immediate area of the strike to systemic changes that may occur as a result of such a large impact.

Technology Link:

On the Moon Educator Guide

http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/On_the_Moon_Guide.html

features a *Heavy Lifting* activity to help students visualize the challenges in designing space probes that can collect surface samples on other planets and the Moon.

Interdisciplinary Link: Link to Math – Use craters made in class to calculate π .

Instructor's Guide

Day Six - Highlands

Objective: Students will understand the process of plate tectonics in the formation of mountains on Earth and contrast those processes with those that created the lunar highlands. Students will make a model of the Moon's surface and consider the geologic processes and formation of each area.

Materials: prepared box and paper for Engage demonstration; lunar map, photographs of the Moon, tray, sculpturing tools, toothpick flags, and clay, plaster of Paris, or play dough

Engage: Begin the class with a demonstration of *Plate Tectonics With a Box* found at http://volcano.oregonstate.edu/vwdocs/vwlessons/activities/p_number5.html. Emphasize those interactions that result in the formation of mountains, stressing that these are processes that occur on Earth. You may also want to include the animation of plate tectonics at http://www.knowitall.org/nasa/simulations/plate_movements/index.html.

- Discuss where on Earth the various types of faults are active
- Ask students if this process is happening on the Moon

Explore: Use the directions for *Lunar Surface* activity. (Omit item seven. Item one might be assigned as homework if appropriate for your students.) Students refer to a map of the Moon to make a model of the Moon's features as shown. Have students explain how each feature in their models might have been formed. http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Lunar_Surface.html (This activity is part of the *Exploring the Moon* Teachers Guide at <http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Exploring.the.Moon.html>)

Explain:

Vocabulary: highlands, rill

- Students copy vocabulary, definitions, and concepts into their Moon Journals.

Concept

- Return to opening question to review student ideas about formation of highlands on the Moon. Now that they have modeled the Moon, are those ideas the same?
- Earth and Moon have different processes acting today. Stress the difference between formation of mountains on Earth and highlands on the Moon. Lead them to understand:
 - Earth's mountains are formed as the result of plate tectonics.
 - There are no plate tectonics active on the Moon.
 - Lunar highlands are thought to have been formed through successive lava flows.

Evaluate: Give students the Concept Quiz to cover material presented so far.

Elaborate: The *Lunar Landing Sites* activity can be completed in whole – design a vehicle to carry a research team to the Moon, choose a landing site with safety and exploration in mind, and present findings to the class – or in part, with students using the models they have just created to plot landing sites. http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Lunar_Landing.html

Technology Link: The *On Target* activity in the *On the Moon Educator Guide* at http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/On_the_Moon_Guide.html uses a landing design challenge that can illustrate the importance of NASA's choice to landing the Apollo missions in craters instead of on highlands.

Interdisciplinary Link: Link to Geography – Compare map of Earth's mountain ranges to the Moon's highland ranges.

Instructor's Guide

Day Seven - Regolith

Objective: Students will investigate the bombardment of micrometeorites on the Moon by making simulated regolith and observing its properties.

Materials: Toasted white bread, toasted golden wheat bread, small pan, sand paper/ nail file/ or edge of ruler, ice cube with sand inside, tray, and a fist-size rock for *Regolith Formation* activity; OR microscopes or magnifiers, box lids, boxes, cinnamon sugar graham crackers, white powdered sugar, cake mini-donuts or giant gum drops, newspapers, index cards, clear packing tape, wire strainers, scissors, hole punch, markers, small containers, and safety glasses for *Making Regolith* activity

Engage:

Show *Two New NASA LRO Videos: See Moon's Evolution, Take a Tour*

http://www.nasa.gov/mission_pages/LRO/news/vid-tour.html Ask students what they think happens to dust from crater impacts; guiding them to the explanation that all dust will end up as regolith, both on Earth and on the Moon.

Explore:

Use the directions for *Regolith Formation* or *Making Regolith* to guide the students through the activity. The *Regolith Formation* activity features scraping and dropping methods of making breadcrumbs to simulate regolith formation on the Moon and the Earth.

http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Regolith_Formation.html

OR

Making Regolith uses different food materials to simulate the processes of regolith formation.

http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Making_Regolith_Activity.html

(These activities are part of the *Exploring the Moon* Teachers Guide at

<http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Exploring.the.Moon.html>)

Explain:

Vocabulary

- regolith, meteoritic bombardment, weathering, erosion
- Students copy vocabulary, definitions, and concepts into their Moon Journals.

Concept

- The Earth's regolith is formed by weathering; the Moon's regolith is formed by meteoric activity
- Additional information on the Moon's surface can be found at <http://www.astrosociety.org/education/publications/tnl/13/13.html>.

Evaluate:

The completed lab sheet and questions are the assessments for the lesson.

Elaborate and Technology Link:

Students can conduct the *Moon Archeology* activity at

<http://lunar.arc.nasa.gov/education/activities/active5a.htm> for a simulated experience in mining the resources of the Moon.

Interdisciplinary Link:

Link to Art – Teams of students can make a creative poster illustrating the features of the lunar surface.

Instructor's Guide

Day Eight – Mapping 1

Objective:

Students will identify and measure features of craters to determine relative ages of the lunar surface.

Construct explanations for patterns in geologic evidence to determine the relative ages of a sequence of events that have occurred in Earth's past.

Materials:

Black and white pictures of the lunar surface (4"x6") (we provide a set here: https://www.dropbox.com/s/zdgtkpz28raxjr0/CraterAge_Images_small.pdf), scale (<https://www.dropbox.com/s/xxvwlpt32gbxmjr/crater%20scale.pdf>), grid (<https://www.dropbox.com/s/rghy654l6xt7ujq/lunar%20surface%20age%20sample%20grid.pdf>), overview image (<https://www.dropbox.com/s/xj0567p2lwfonkb/Screen%20Shot%202012-11-16%20at%203.56.01%20PM.png>), markers, (preferably silver Sharpies), tape, large poster board, colored cellophane or see-through plastic folders in four colors: blue, green, yellow, red

Background:

The most obvious features on the Moon are the craters, or scars left from impacting rocks that have crashed into the Moon since its formation. We do not see many craters on Earth because active geologic processes and erosion erase these features rather quickly. On the Moon, however, there are no active tectonic processes and no weathering due to wind and water, so a record of these impacts is preserved.

It follows that, given a fairly steady rate of impacts, that the older a surface is, the more craters it will have. Although the cratering rate is not strictly steady over all of geologic time, lunar geologists do use the density of craters over a given surface to determine *relative ages*, that is, to tell which surfaces are older and which are younger.

This activity uses images from the Lunar Reconnaissance Orbiter. You will have your students count the craters above a certain size (5 km) there are in each image. Each group will then classify the images by number of craters. This establishes the relative age of that area of the surface. The pictures will come together at the end to make one large map to illustrate how the surface age changes over a larger area of the Moon.

Engage:

Share the video "Lunar Craters Through 8" Telescope" at <http://www.youtube.com/watch?v=k4YLMASou78> or "Lunar Moon Crater Copernicus Close Up at <http://www.youtube.com/watch?v=AYa1LyVWiaQ>

Explore:

Lunar Surface Age Activity – Students may work individually or with partners to trace and count craters on 3-5 lunar surface pictures.

1. Hand out the pictures of the lunar surface to your students. These images will be marked so that you can put them back together at the end of the activity.
2. Ask the students to find and circle all of the craters in their image with the silver Sharpie. Provide each student with the attached scale marker. They should only worry about circling craters that are larger than one square on the scale. This square represents 5 km.
3. Have the students count up the number of craters in their pictures and cover each one with a colored square of cellophane or a plastic see-through folder based on the following guide:

- a. 0-3, blue
 - b. 4-6, green
 - c. 7-10, yellow
 - d. 11+ red
4. Have the students work together to arrange the colored pictures back into one large image on poster board based on the markings to facilitate analysis of the Moon's history.

Explain:Discussion/connections

- What observations can you make about the section of the Moon that we've put together?
- Which color represents the oldest surface?
- Which is the youngest?
- What does the large image tell you about the age of the surface in this area?

Vocabulary

- Lunar Reconnaissance Orbiter, crater, impactor, asteroid
- Students will add and define LRO in their Moon Journals.

Concept

- The surface of the moon can be mapped using images from the LRO.
- Individual craters have characteristics dependent on the history of their formation
- Characteristics of craters give clues to their relative age

Evaluate:

Students can hand in their completed lunar surface pictures for assessment.

Elaborate:

Students may work with other surface pictures to improve their identification skills. Professional scientists take these relative ages and put them on an absolute age scale by using radioisotope moon rocks that came back from Apollo and other missions

Interdisciplinary Link:

Link to Social Studies – Research the history of people who have mapped the Moon

Link to Math – Graph the frequencies of the diameters of craters.

Instructor's Guide

Day Nine – Mapping 2

Objective:

Students will be introduced to the *Moon Mappers* website.

Materials:

Smart board, computers, internet access

Engage:

Review information from the mapping activity on Day 8. Use a Smart board or other projection system to give students a tour of the *CosmoQuest* and *Moon Mappers* web pages as they follow along on their own computers. Be sure to familiarize yourself with the software beforehand using the suggested tutorials.

Explore:

Students will begin to identify craters at *Moon Mappers* website.

Explain:

Concepts

- Different sized craters are found on the Moon
- Craters give us clues to the processes that formed the Moon, Earth, and other celestial bodies
- Citizen scientists are needed to help map the surface using images from the Lunar Reconnaissance Orbiter (LRO)

Evaluate:

Track the number of maps students classify as an evaluation of their class work.

Elaborate:

Encourage students continue identifying craters at *Moon Mappers* web site on their own.

Technology Link:

Students will become familiar with the online technology used to map craters on actual pictures of the Moon.

Interdisciplinary Link:

Link to Social Studies – Students use the internet and other resources to research the history of people who have mapped the Moon.

Instructor's Guide

Days Ten and Eleven - Anomalies

Objective:

Students will investigate and explain various lunar anomalies: moonquakes, absence of volcanoes, number of maria on the far and near sides of the moon, and magnetic fields.

Materials:

maps of the moon, background information on the moon, "Moon ABCs Fact Sheet," art supplies, supplies for discrepant event of choice

Engage:

Use the "Moon Illusion" discrepant event to motivate students to investigate anomalies on the moon. (Other possible discrepant event activities are listed below.)

- Display two pictures of the Moon: one on the horizon, and one overhead
- Ask students to explain why the Moon looks bigger on the horizon. (A good explanation appears at <http://news.discovery.com/space/moon-horizon-optical-illusion.html>; a NASA "Launchpad: Moon Magic" video explains the possible reasons starting at the 3:15 mark in the video.)
- Explain that student teams will tackle other Moon mysteries today.

Explore:

Use the directions for *Moon Anomalies* to divide the class into teams of 3-4 students. Assign each team a Moon anomaly question sheet to investigate and explain. Students use Moon Journals and websites for additional information to support their ideas and present their hypotheses to the class using power point or a poster. http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Moon_Anomalies.html (This activity is part of the *Exploring the Moon* Teachers Guide at <http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Exploring.the.Moon.html>)

Note: This can be a one or two-day lesson, depending on the extent of student presentations.

Explain:

Concepts

- There may be fewer Moonquakes because there are fewer movements inside the Moon.
- Fractures on the Moon's surface may have provided easy access to the surface for magma.
- Differing thicknesses in the Moon's crust may account for the number of maria on the far and near sides.
- The Moon's core may be solidified, so motions fast enough to generate a magnetic field do not occur.

Students should describe anomalies in their Moon Journals.

Evaluate:

Class presentations serve as the day's assessment

Elaborate:

Explore similar anomalies on Earth

Interdisciplinary Link:

Link to Language Arts – Students can write an imaginative short story about a Moon mystery

(continued...)

Other Possible Discrepant Event Demonstrations:

(A discrepant event is one that surprises students because it does not appear to follow basic rules of nature and has an unexpected result.)

- Egg sucked into a bottle at <http://www.teachscienceandmath.com/tag/science-discrepant-events/>
- The Punctured Can: Puncture three holes at different heights in a large juice can, or a 2 Liter plastic bottle. Set the container in a large pan to catch the water when it pours out. Cover each hole with a piece of plastic tape. Now fill the container with water. Ask the students to predict what will happen if the plastic tape is removed from each hole. Students should be encouraged to draw a diagram illustrating their prediction. Now remove the pieces of tape (very quickly), and have the students observe. Invite the students to explain their observations by comparing their prediction to what they observed. Concepts: pressure, water pressure.
- The Mini-Telescope: Show the students two lenses. (Hand lenses will work just fine.) Invite the students to use the lenses in combination to enable them to see distance objects (a picture or chart on a wall of the classroom). The first challenge is for the students to figure out how to hold the lenses in relationship to each other. (Hint for the teacher: hold one lens up to one of your eyes; hold the other at arms length in front of the lens to your eye. Move the lens at arms length toward and away from the eyepiece until objects are focused.) Students will also notice that the images they see are up-side-down. Invite them to illustrate their explanation of this phenomenon.

Instructor's Guide

Day Twelve - Exploration

Objective:

Students will learn about the locations and geology of the six Apollo landing sites.

Materials:

Lunar maps with latitude and longitude grid, "Apollo Landing Sites Chart," Moon globe. If no maps or globe are available, try Google Moon: <http://www.google.com/moon/>

Engage:

Show video of Apollo 11 landing at <http://video.google.com/videoplay?docid=1416393771637021814>

Explore:

Use the directions for *Apollo Landing Sites* to guide the students through the activity. (Part of the *Exploring the Moon* Teachers Guide at

<http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Exploring.the.Moon.html>)

In *Apollo Landing Sites* at

http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Apollo_Landing.html, students will analyze the locations and geologic features of each of the six Apollo landing sites.

Explain:

Vocabulary

- latitude, longitude, Sea of Tranquility, Ocean of Storms, Sea of Serenity
- Students copy vocabulary, definitions, and concepts into their Moon Journals.

Concept

- Apollo landing sites were chosen for their geologic interest and accessibility.

Evaluate:

The assessment is the completed lab sheet

Technology Link:

The *Lunar Roving Vehicle* activity at

http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Lunar_Roving.html or the *Roving on the Moon* activity in the *On the Moon Educator Guide* at

http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/On_the_Moon_Guide.html

provides an opportunity for students to use their knowledge of lunar terrain to design a vehicle to explore the Moon.

Elaborate:

The *Lunar Roving Vehicle* activity at

http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Lunar_Roving.html provides an opportunity for students to use their knowledge of lunar terrain to design a vehicle to explore the Moon.

Interdisciplinary Link:

Link to Social Studies – View video footage of lunar landings and ask students to write an eyewitness newspaper article about the landing

Instructor's Guide

Day Thirteen – Marking Craters

Objective:

Students will practice identification of lunar craters on the *Moon Mappers* web site.

Materials:

computers, smart board

Engage:

Review procedures for crater marking.

Explore:

Students – either individually or in teams – identify and map craters at the *Moon Mappers* web site.

Explain:

None

Evaluate:

The number of crater maps completed by each student can be used both as an evaluation and an incentive for students to stay on task.

Elaborate:

Students continue to identify craters at the *Moon Mappers* web site on their own.

Technology Link:

Students will continue to use the online technology to map craters on actual pictures on the Moon.

Interdisciplinary Link:

Multidiscipline – Use internet resources to create a PowerPoint presentation comparing lunar surface features and surface features of the Earth.

Instructor's Guide

Day Fourteen - Review

Objective:

Students will review concepts and vocabulary introduced in the unit.

Materials:

Moon Journals

Engage:

Preview the material that will be covered in the test, highlighting the format of the test, i.e. multiple choice only, lab practical, etc.

Explore:

None

Explain:

Explain concepts as necessary. It is suggested that a game format such as Trivial Pursuit, Jeopardy, etc. be used to keep the students engaged throughout the review.

Evaluate:

None

Elaborate:

None

Interdisciplinary Link:

None

Instructor's Guide

Day Fifteen – Assessment

Objective:

Evaluation

Materials:

Paper, pencil, test

Suggestions for an optional lab practical:

- Crater from day five activity marked with numbered flags for students to identify crater features
- Samples of clay stratigraphy from day four for students to identify oldest layer
- Maps from days eight, nine, and thirteen with tagged craters so students can identify oldest craters, surface features, etc.

Engage:

Prepare students for test, as necessary.

Explore:

None

Explain:

None

Evaluate:

Test

Elaborate:

Celebrate the successful completion of the unit by making the *Lunar Ice Cream* found at <http://lunar.arc.nasa.gov/education/activities/active12a.htm>

Interdisciplinary Link:

None

Appendix A

Assessments

Table of Assessments

Day	Formative Assessment	Summative Assessment	Performance (“Non-traditional”) Assessment
1	Pretest, Venn diagram in Moon Journal		Venn diagram, Elaborate activity in Moon Journal
2	Lab sheet, content questions, Moon Journal		Moon Journal, rocket/spacecraft design challenge
3	Lab data table, content questions, Moon Journal		Moon Journal, <i>Touchdown</i> technology design challenge
4	Moon Journal	Vocabulary quiz	Moon Journal
5	Lab data table, content questions, Moon Journal		Moon Journal, <i>Heavy Lifting</i> technology design challenge
6	Constructed map of Moon’s surface, Moon Journal	Concept quiz	Constructed map of Moon’s surface, Moon Journal, <i>Lunar Landing Sites</i> activity, <i>On Target</i> activity
7	Lab sheet, content questions, Moon Journal		Moon Journal, <i>Moon Archeology</i> activity
8/9	Number of craters mapped at <i>Moon Mappers</i> website, Moon Journal	Crater identification map	Moon Journal, crater identification map, craters mapped at website
10/11	Question sheet, Moon Journal, class presentations on anomalies		Moon Journal, class presentations
12	Lab sheet		<i>Lunar Roving Vehicle</i> design project
13	Number of craters mapped at <i>Moon Mappers</i> website		Number of craters mapped at <i>Moon Mappers</i> website
14	Review game results, Moon Journal		Verbal answers during review game, Moon Journal
15	Moon Journal	Post test	Moon Journal

Name _____

Lunar Exploration Pretest

Match the following words with their definitions:

- | | |
|-------------------------------|--|
| 1. _____ Planetary geologists | A. The study of rock layering |
| 2. _____ Highlands | B. Processes that cause rocks to crack, crumble, or decay |
| 3. _____ Mare | C. Long trenches or valleys observed on the Moon's surface |
| 4. _____ Regolith | D. The separation of minerals as magma cools |
| 5. _____ Erosion | E. Circular feature caused by an object smashing into a surface |
| 6. _____ Impact Crater | F. Blanket of material surrounding a crater thrown out by an impact event |
| 7. _____ Rilles | G. Bright streaks extending great distances from a crater |
| 8. _____ Rays | H. Scientists who study the formation, structure, and processes that change Earth and other planetary bodies |
| 9. _____ Terrain | I. Large, dark areas on the surface of the Moon |
| 10. _____ Magma | J. The wearing away of a planetary body's surface as water, wind, or other natural agents move materials from place to place |
| 11. _____ Differentiation | K. Light-colored, mountainous areas on the surface of the Moon |
| 12. _____ Ejecta | M. Molten rock material originating under the crust of a planetary body |
| 13. _____ Stratigraphy | N. Of or pertaining to the Moon |
| 14. _____ Lunar | O. Loose, fragmented material on the Moon's surface |
| 15. _____ Weathering | |

16. Name three kinds of rocks and explain how they are formed.

17. What is the difference between a mineral and a rock?

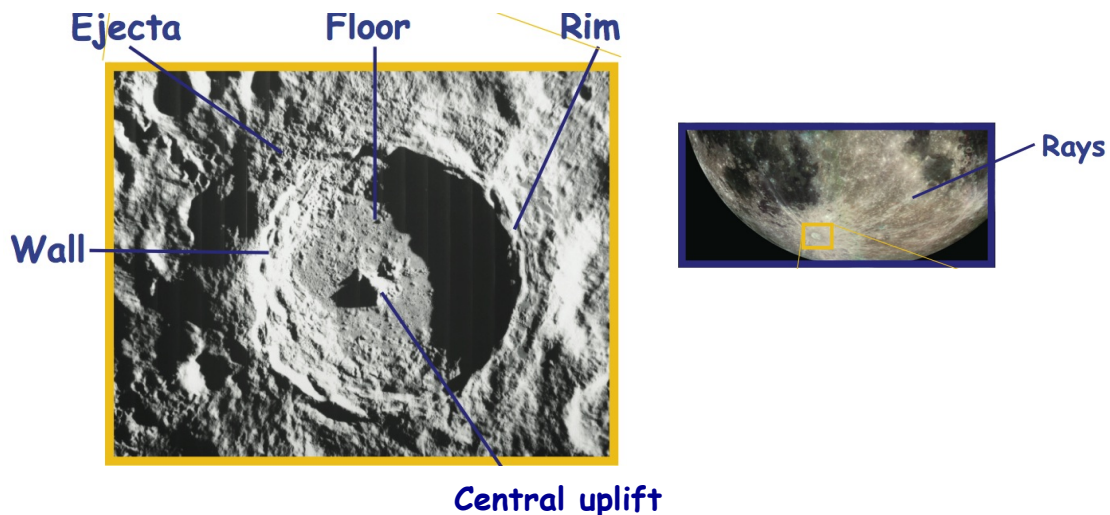
18. Does weathering occur on the moon? Why or why not?

19. What was the Apollo program?

20. Draw and label a lunar impact crater. Use the following words: floor, wall, rays, ejecta, central uplift, and rim.

Lunar Exploration Pretest Key

1. H
2. K
3. I
4. O
5. J
6. E
7. C
8. G
9. L
10. M
11. D
12. F
13. A
14. N
15. B
16. Sedimentary (formed from hardened deposits of sediments), metamorphic (rock formed from pre-existing rocks as a result of intense heat, pressure, or chemical processes), igneous (rock formed from cooled and hardened magma)
17. Minerals are naturally formed solids with a crystalline structure and a specific chemical make up; whereas rocks are solid material made of minerals, forming part of the surface of the Earth and other planetary objects
18. Weathering does not occur on the Moon as it does on the Earth because there is no rain, wind, or other natural weathering agents.
- 19.



20. The Apollo program was the spaceflight effort carried out by NASA that landed the first humans on Earth's Moon.

Name: _____

Vocabulary Quiz

- A. Planetary Geologist
- B. Sedimentary
- C. Mineral
- D. Density
- E. Magma
- F. Rock
- G. Igneous
- H. Lunar
- I. Metamorphic
- J. Differentiation

1. _____ Separation of minerals in hot magma
2. _____ Solid material made of minerals forming part of the surface of the Earth and other planetary bodies
3. _____ Rock formed from preexisting rocks as a result of intense heat, pressure, or chemical process
4. _____ Scientist who studies the formation, structure, history, and processes that change Earth and other planetary bodies
5. _____ Naturally formed solid with a crystalline structure and a specific chemical make up
6. _____ The degree of compactness; mass per unit volume
7. _____ Rock formed from cooled and hardened magma
8. _____ Layer of magma, hundreds of kilometers thick, thought to have covered the Moon 4.5 billion years ago
9. _____ Pertaining to the Moon
10. _____ Type of rock formed from hardened deposits of sediments

Vocabulary Quiz Key

1. J
2. F
3. I
4. A
5. C
6. D
7. G
8. E
9. H
10. B

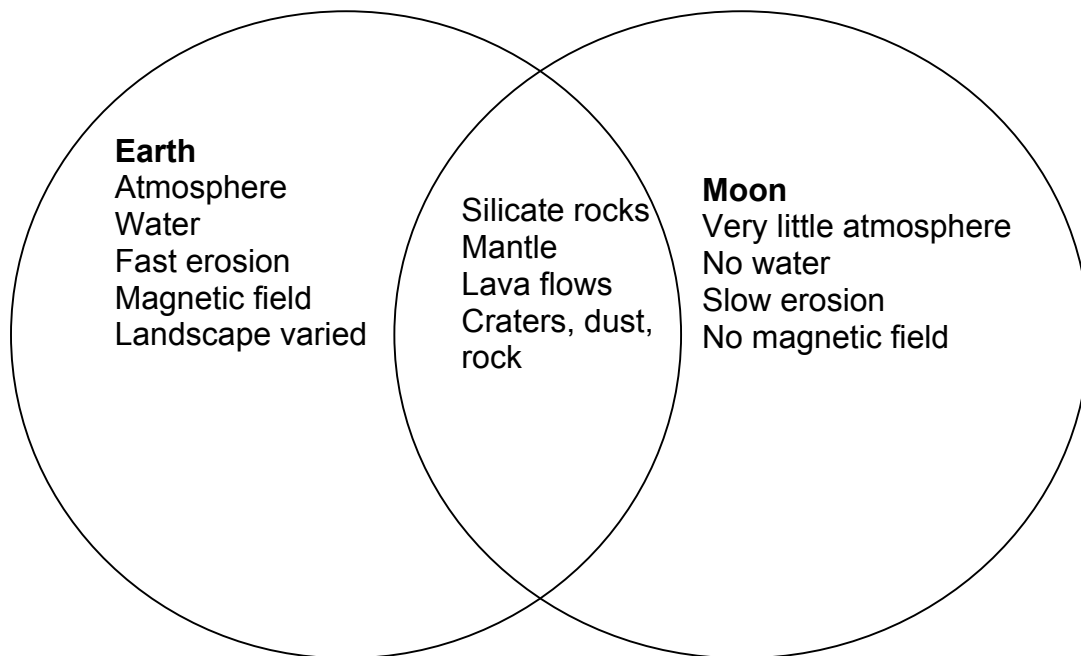
Name _____

Lunar Quiz

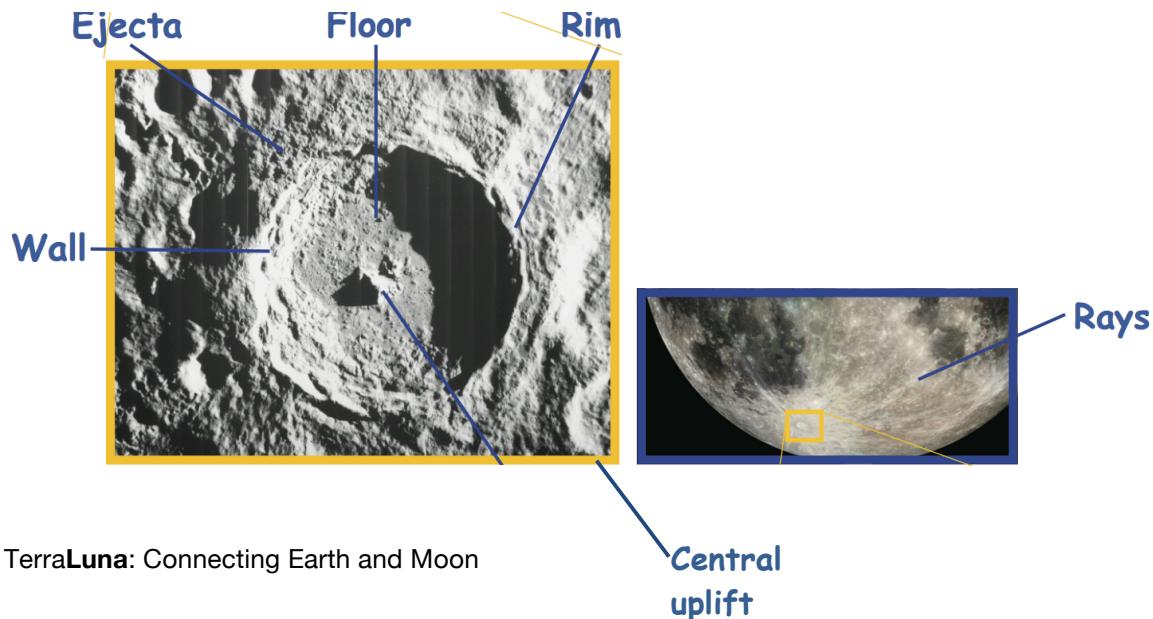
1. Explain how minerals separate from one another in a magma ocean.
2. What is the probable origin of Moon rocks?
3. Draw a Venn diagram to compare and contrast the surface features of the Earth and Moon.
(Include at least 4 features)
4. What is stratigraphy?
5. Draw a picture of an impact crater and label it using the following words: rim, wall, ejecta, rays, central uplift, floor

Lunar Quiz KEY

1. When planets begin to melt, the materials in them begin to separate from one another. The heaviest materials, such as metallic iron, sink to form cores. Low-density magmas rise forming crusts. This is called differentiation.
2. The similarity between Earth and Moon rocks indicates that they are a result of an impact by an asteroid or meteoroid when the solar system was formed.
3. A possible diagram:



4. Stratigraphy is the study of rock layering.
- 5.



Lunar Exploration Posttest

Match the following words and their definitions:

- | | |
|-------------------------------|--|
| 1. _____ Erosion | A. Scientists who study the formation, structure, history, and processes that change Earth and other planetary bodies. |
| 2. _____ Lunar | B. Molten rock material originating under the crust of a planetary body |
| 3. _____ Planetary geologists | C. Circular features caused by objects crashing into a surface |
| 4. _____ Terrain | D. Of or pertaining to the Moon |
| 5. _____ Regolith | E. The wearing away of the surface of a planetary body by water, wind, or other natural agents |
| 6. _____ Maria | F. Loose, fragmented material on the Moon's surface |
| 7. _____ Impact craters | G. An area of land or ground with all its natural components |
| 8. _____ Highlands | H. Large, dark areas on the surface of the Moon |
| 9. _____ Differentiation | I. Separation of minerals in a magma ocean |
| 10. _____ Magma | J. Light-colored, cratered areas on the surface of the Moon |

Multiple Choice

11. _____ Igneous rocks are formed:
- A. by cementing, compacting, and hardening existing rock or the bones, shells, and pieces of living things
 - B. from molten liquid minerals that lie beneath the earth's crust
 - C. by movement of tectonic plates
 - D. by applying pressure and temperature to existing rock
12. _____ Sedimentary rocks are formed:
- A. by cementing, compacting, and hardening existing rock or the bones, shells, and pieces of living things
 - B. from molten liquid minerals that lie beneath the earth's crust
 - C. by movement of tectonic plates
 - D. by applying pressure and temperature to existing rock
13. _____ The size of a crater depends upon:

- A. the mass of an impactor
- B. the velocity of an impactor
- C. kinetic energy
- D. all of the above

14. _____ Stratigraphy is:
- A. the strategy for studying the moon
 - B. the study of rock layering
 - C. studying the location of impact craters
 - D. separating rocks from minerals

15. _____ The Apollo Mission:
- A. was the only program to land on the Moon
 - B. was designed to explore the geology of the Moon
 - C. was not dangerous
 - D. provided no useful data

True or False

(Write the words true or false in the blank)

16. _____ The Moon is less than 1/3 the size of the Earth
17. _____ The Moon has very little atmosphere
18. _____ Gravity on the Moon is greater than gravity on Earth
19. _____ The Lunar Prospector sent data about the Moon back to Earth.
20. _____ The Moon's magnetic field is weaker than the Earth's

Short Answer

21. What is the difference between a mineral and a rock?

22. Does weathering occur on the Moon? Why or why not?

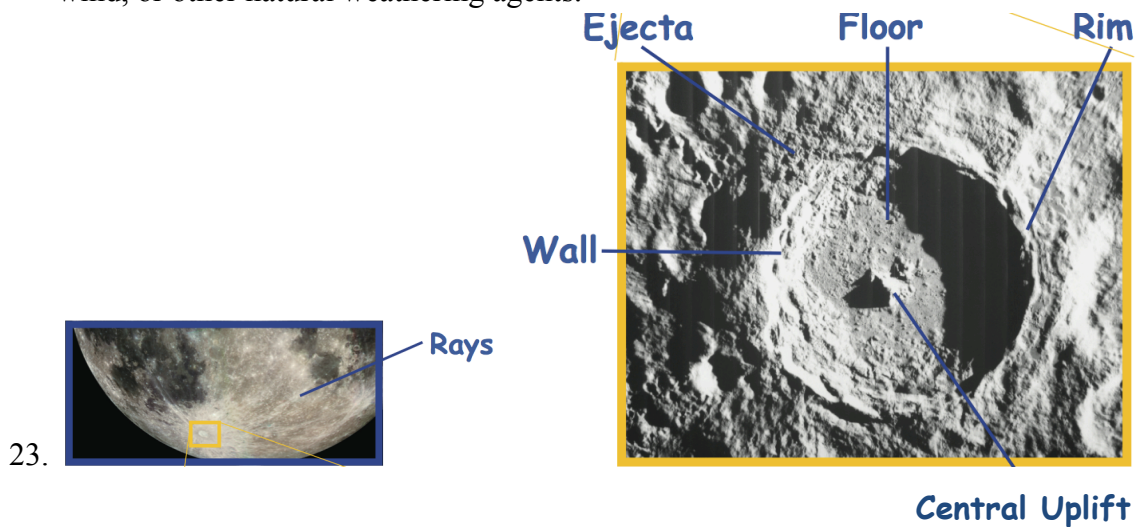
23. Draw and label a lunar impact crater. Use the following words: floor, wall, rays, ejecta, central uplift, and rim.

24. Compare the process of regolith formation on the Earth and on the Moon.

25. Make a Venn diagram comparing and contrasting the surface of the Earth and Moon.

Posttest Key

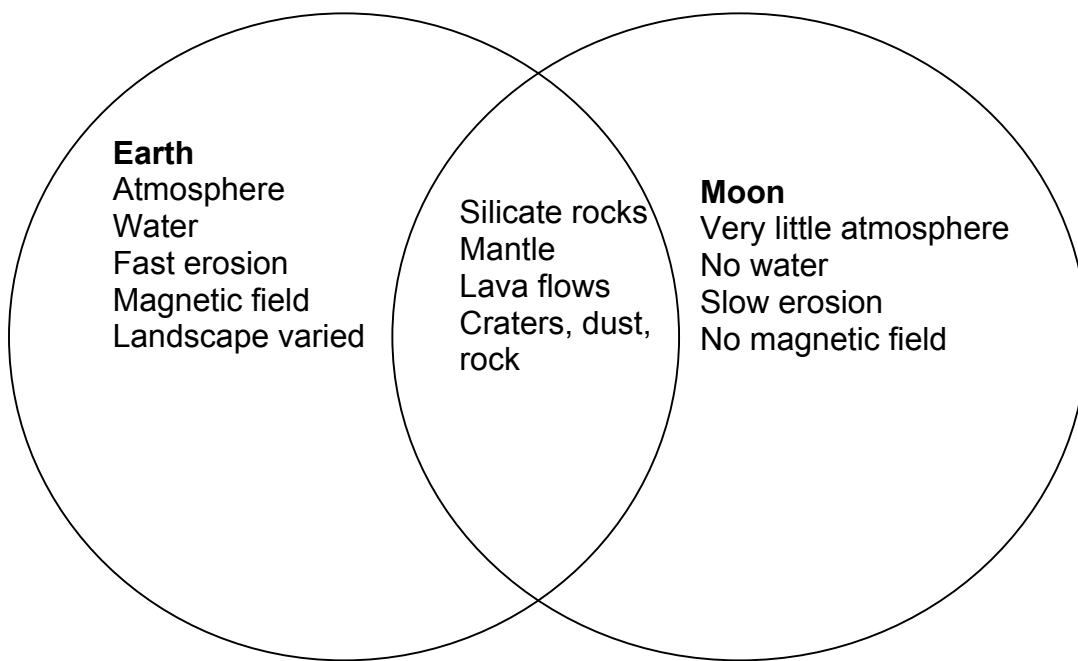
1. E
2. D
3. A
4. G
5. F
6. H
7. C
8. J
9. I
10. B
11. B
12. A
13. D
14. B
15. B
16. True
17. True
18. False
19. True
20. True
21. Minerals are naturally formed solids with a crystalline structure and a specific chemical makeup; whereas rocks are solid material made of minerals, forming part of the surface of the Earth and other planetary objects.
22. Weathering does not occur on the Moon as it does on the Earth because there is no rain, wind, or other natural weathering agents.



24. Regolith on the Moon is a product of meteoritic bombardment and is the debris thrown out of the impact craters. Generally, the older the surface, the thicker the regolith. On the

Earth, regolith is a product of weathering which causes rocks to fragment, crack, crumble, or decay. The processes involved can be physical such as wind or freezing water, chemical such as decaying minerals in water and acids, or biological such as plant roots widening cracks.

25. A possible Venn diagram:



Appendix B

Educator Feedback/Unit Evaluation

TERRALUNA Educator Survey

Name _____ School _____ I teach _____ grade.

1. Using the rubric below, please rate each activity we completed during this workshop.
Write a number from 1 to 4 in the "Rating" column and add any suggestions or observations in "Comments."
- 2.

Rating Rubric

Not engaging	Somewhat engaging	Engaging	Very engaging.
1	2	3	4

Title	Rating	Comments
Moon/Earth picture classification and Venn Diagrams		
Reaping Rocks		
Differentiation on Lunar Surface		
Lava Layering		
Impact Craters		
Crater mapping at <i>CosmoQuest</i> web site		
Lunar Surface		
Making Regolith		
Lunar Art		
Lunar Surface Aging		
Discrepant Events		
Lunar Ice Cream		
<i>Launch It</i> engineering activity		
<i>Touchdown</i> engineering activity		
<i>On Target</i> engineering activity		
<i>Archeology: Chip Mines</i> engineering activities		

2. Is the unit content grade-appropriate for your students?

3. Is the unit the right length?

Too long ----- right length ----- too short

Comments:

4. What might prevent you from using this unit in your classroom?

5. If you have any other helpful comments or suggestions, please write them below.

Please email this survey to
educate@cosmoquest.org.

Thank you so much for your help!
The CosmoQuest Education Team